AGRICULTURAL ENERGY CENTRE

EVALUATION OF DEHUMIDIFIERS

IN A

ROSE GREENHOUSE

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INTRODUCTION

High humidity levels in a greenhouse can cause many problems with plants. The key factors in controlling moisture at the tissue surfaces involve: reducing the moisture content of the air, keeping the tissue surfaces warm, and maintaining air circulation. Greenhouse growers have relied on heat, ventilation, and air circulation to control relative humidity.

The plant temperature and the rate of nutrient uptake by the roots are proportional to water use rates (transpiration) from the leaves and flowers. Under high relative humidity conditions the rate of nutrient uptake and transport is reduced, which may slow the normal growth pattern.

High moisture levels in a greenhouse can also increase fuel use in several ways. Evaporation of free water in the greenhouse or from plant surfaces requires heat. This heat is taken from the greenhouse air. Cold surfaces in the greenhouse will condense water vapour at a rate depending on the surface temperature, air movement and greenhouse air relative humidity.

A dehumidifier can reduce the relative humidity in a greenhouse without the need for ventilation. The fuel savings from dehumidification are twofold. First since relative humidity control with a dehumidifier does not require ventilation, no heat is required to preheat cold incoming air. Secondly the dehumidifier recovers the latent heat from the greenhouse air which passes through it and puts it back in as sensible heat.

In addition since the ventilation rate is reduced, the CO_2 level in the greenhouse is not reduced, therefore plants will do better. This is especially important if CO_2 enrichment would be required to maintain suitable CO_2 levels.

Thus using a dehumidifier to control relative humidity in a greenhouse should reduce the winter ventilation requirements and save heating energy.

OBJECTIVE

To evaluate the performance of two dehumidifiers in a commercial rose growing greenhouse.

TEST SYSTEM

The test greenhouse is an arched roof, gutter-connected greenhouse, three bays wide with overall dimensions of 24m x 96m x 4m eave height. This is a modern rose production facility utilizing computer control for heating, ventilation, fertilization and watering as well as supplemental growth lights. The steel greenhouse frame is covered with a double poly air-inflated covering on the roof and sidewalls. The north end wall consists of coroplast sheets. The gables are sprayed with polyurethane foam insulation. The south end wall is glass and forms a common wall with an adjoining greenhouse.

Two Dry-O-Tron Model #DA24 dehumidifiers are installed in the greenhouse as illustrated in Figure #1. These dehumidifiers have 5 Ton Compressors. The dehumidifiers are situated at the north end of the greenhouse mounted on stands 3m high. Roses are grown in beds which run across the three bays.

MONITORING

The following parameters were measured to determine the effectivenss of the dehumidifiers:

PARAMETERS	RECORDING EQUIPMENT
dry bulb and wet bulb temperatures relative humidity	Kaye Digi Stip III datalogger
condensate from dehumidifiers	pumped from condensate tank through water meter
electrical energy consumption	kilowatthour meter
air flow rate through dehumidifiers	Velometer

RESULTS

Wet bulb and dry bulb air temperatures were taken before entering and after leaving the dehumidifier. As well a remote station, away from the dehumidifiers was used to determine average greenhouse air wet and dry bulb temperatures. The remote wet and dry bulb measurements were used to determine

if the air entering the dehumidifier was representative of the greenhouse air conditions. In all cases the thermocouples were aspirated to get a true reading of the air temperatures.

Condensate from both dehumidifiers was drained into a tank and pumped through an accumulating water meter into a drain. In this way the amount of condensate could be measured.

Table #1 summarizes the measured air conditions for one day. The air conditions entering and exiting the dehumidifier are tabulated. The change in enthalpy between entering and exiting conditions was determined from the psychrometric chart.

Electrical energy consumption of the dehumidifiers was measured by a kilowatthour meter. Power consumption per hour of operation was determined by using the following formula:

$$kWh/h = \frac{\text{Kh FACTOR x Number of revolutions}}{\text{Time (seconds)}} \times 3.6$$

Where : Kh FACTOR = 36
Number of revolutions = 5
Time for 5 revolutions = 52.5 seconds
(average of 6 tests)

$$\therefore \text{ Power Consumption for both dehumidifiers} = \frac{36 \times 5}{52.5} \times 3.6$$
$$= 12.34 kWh/h$$

∴ Combined the dehumidifiers used 12.34kWh/h of operation.

Air flow rates from the dehumidifiers were measured by means of a velometer. Each unit has an air flow rate of 1040L/s. Therefore a total of 2080L/s of air was being recirculated within the greenhouse.

Looking at the Δ Enthalpy in Table #1, it can be seen that these values vary over time, from 0.5 to 8.0kJ/kg of dry air. Since the datalogger was not programmed to measure temperatures only when the dehumidifiers were operating, some of the hourly readings might have occurred when the units were off.

Entering and exhausting air temperatures should be noticeably different when the units are operating. Therfore readings for Δ Enthalpy of 5 to 8kJ/kg are realistic. For calculation an average Δ Enthalpy of 7kJ/kg was used.

$$\text{Energy Ratio} = \text{Coefficient of Performance} = \frac{\text{Energy Output}}{\text{Energy Input}}$$

Energy Output = energy added to the air passing through the humidifier.

$$\text{Mass of air moved per hour} = \frac{2080\text{L/s} \times 60\text{sec/min} \times 60\text{min/h}}{1000 \times .86\text{m}^3\text{/kg dry air}}$$

$$= 8707\text{kg/h}$$

$$\text{Energy added to air} = \text{mass of air moved per hour} \times \Delta H$$

$$= 8707\text{kg/h} \times 7.0\text{kJ/kg}$$

$$= 60949\text{kJ/h}$$

$$\therefore \text{Energy Output} = 60949\text{kJ/h}$$

$$\text{Energy Input} = \text{energy used by the dehumidifier}$$

$$= 12.34\text{kWh/h} \times 3.6 \times 10^3\text{kJ/kWh}$$

$$= 44424\text{kJ/h}$$

$$\therefore \text{Instantaneous Coefficient of Performance} = \frac{\text{Energy Output}}{\text{Energy Input}}$$

$$= \frac{60949\text{kJh/h}}{44424\text{kJ/h}}$$

$$= 1.37$$

This means that the dehumidifiers produce $1.37 worth of heat for each $1.00 worth of electricity used.

Recording hygrothermograph charts can be found in Appendix I. One hygrothermograph was located in the greenhouse with the dehumidifiers. A second unit was located in another part of the range, growing roses at the same stage of growth. It can be seen that the dehumidified greenhouse air relative humidity remained more constant than the relative humidity in the

other greenhouse. In the conventional greenhouse the relative humidity levels dropped below 50% during midday periods. The dehumidified greenhouse relative humidity ranged from 50% to 80% during the same midday period. It is predicted that the roses will not experience as much stress if the relative humidity remains nearly constant.

PROBLEMS

When the dehumidifier system was first installed 500mm diameter poly tubes were used to distribute air from the units throughout the greenhouse. After installation of horizontal air mixing fans throughout this greenhouse, the poly tubes were removed. It was felt that these air mixing fans would do an adequate job of distributing this dehumidified air in the greenhouse. Shortly after the removal of the polytubes two distinct areas of mold growth were noticed on the roses downstream of the dehumidifiers. Each of these areas was approximately three metres wide by ten metres long.

Certain molds require two distinct conditions to develop and multiply. Warm moist conditions are required for the mold to grow, while warm dry conditions are necessary for the mold to produce spores and multiply. The roses in these two particular areas were subjected to both these conditions, warm and moist, and warm and dry due to the cyclic operation of the dehumidifiers. The air exhausting from the units was droppng onto the roses in these affected areas and putting these plants under stress, due to the dryer air.

Since these roses are under stress they are more susceptible to infection by disease causing organisms. A length of perforated poly tube attached to each dehumidifier would distribute the dryer air over a larger area. This retrofit should reduce the possibility of this problem reoccurring.

CONCLUSIONS

1. Dehumidifiers in this rose growing greenhouse do provide a means of controlling relative humidity levels. The greenhouse operating with dehumidifiers had less swing in relative humidity levels than the greenhouse which did not have dehumidifiers.
2. The instantaneous Coefficient of Performance was calculated to be approximately 1.37.

SUMMARY

Dehumidifiers can do a job of controlling excess relative humidity in a greenhouse application. This report describes work which has been done and how this system performs. The economic benefit or payback period for this dehumidification system is difficult to quantify since comparative heating data was not obtained. However, since relative humidity can be reduced to the desired levels without introducing cold outside air, for ventilation, extra heat is not required to warm this air. Thus, we are saving fuel. However, additional benefits of the system such as not depleting CO^2 levels in the greenhouse also have economic merit. Unfortunately this project did not evaluate this benefit.

ACKNOWLEDGEMENTS

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Mr. Dan Van Hooren, Energy Specialist, with the Agricultural Energy Centre, for assisting with the installation and debugging of monitoring equipment and programming of the datalogger.

TABLE 1. TEMPERATURE AND ENTHALPY RELATIONSHIPS - FEBRUARY 28

TIME	DEHUMIDIFIER				
	AIR ENTERING		AIR EXITING		ΔENTHALPY(ΔH)
	WET BULB	DRY BULB	WET BULB	DRY BULB	kJ/kg DRY AIR
0900	16.8°C	19.2°C	18.5°C	23.3°C	5.0
	19.0	21.4	19.9	23.3	3.0
	19.2	20.8	20.7	24.9	4.5
1200	20.3	21.9	21.0	24.8	2.3
	21.8	24.0	22.7	27.4	3.5
	22.0	24.7	22.5	26.7	2.0
1500	21.8	24.4	22.0	26.1	0.5
	20.8	23.2	22.2	27.7	5.0
	18.6	20.4	20.3	25.7	5.5
1800	15.5	17.1	13.0	23.9	6.5
	17.2	20.1	19.9	27.4	8.0
	17.3	20.2	18.2	22.4	3.0
2100	17.5	20.2	18.6	23.3	3.5
	17.8	20.6	18.0	21.1	1.5
	18.0	20.5	18.2	21.4	0.5
000	17.7	20.1	18.1	21.2	0.5
	18.2	20.8	18.6	22.0	1.5
	17.7	20.2	18.1	21.2	1.5
0300	17.5	20.2	19.7	26.0	7.0
	17.5	20.3	17.9	21.3	1.0
	18.0	20.8	19.2	23.7	4.0
0600	18.0	20.8	18.7	22.6	2.0
	18.0	20.7	20.3	27.2	2.0
	18.5	21.1	19.1	22.6	2.0

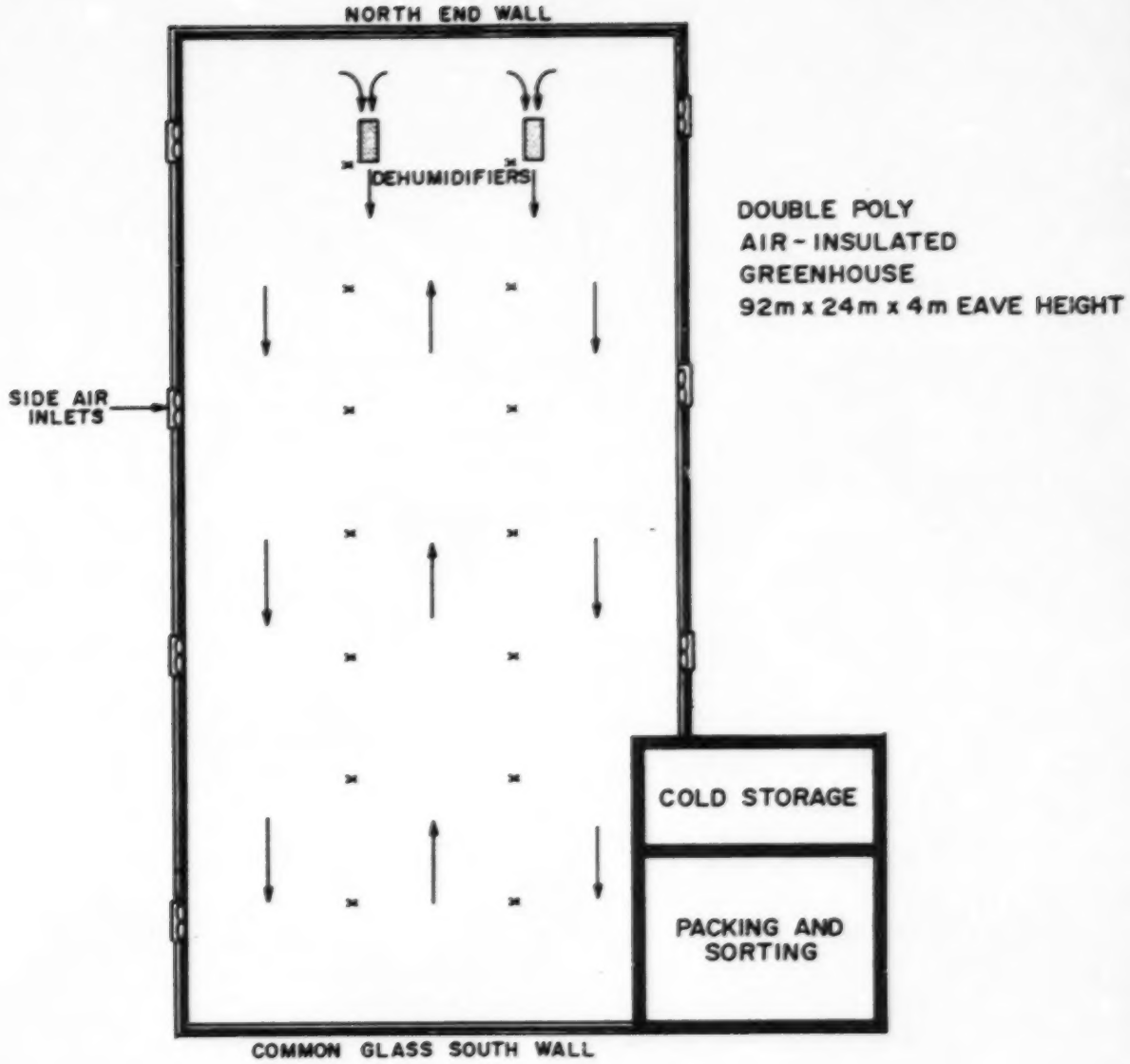


FIGURE 1 - PLAN VIEW OF DEHUMIDIFIERS IN GREENHOUSE

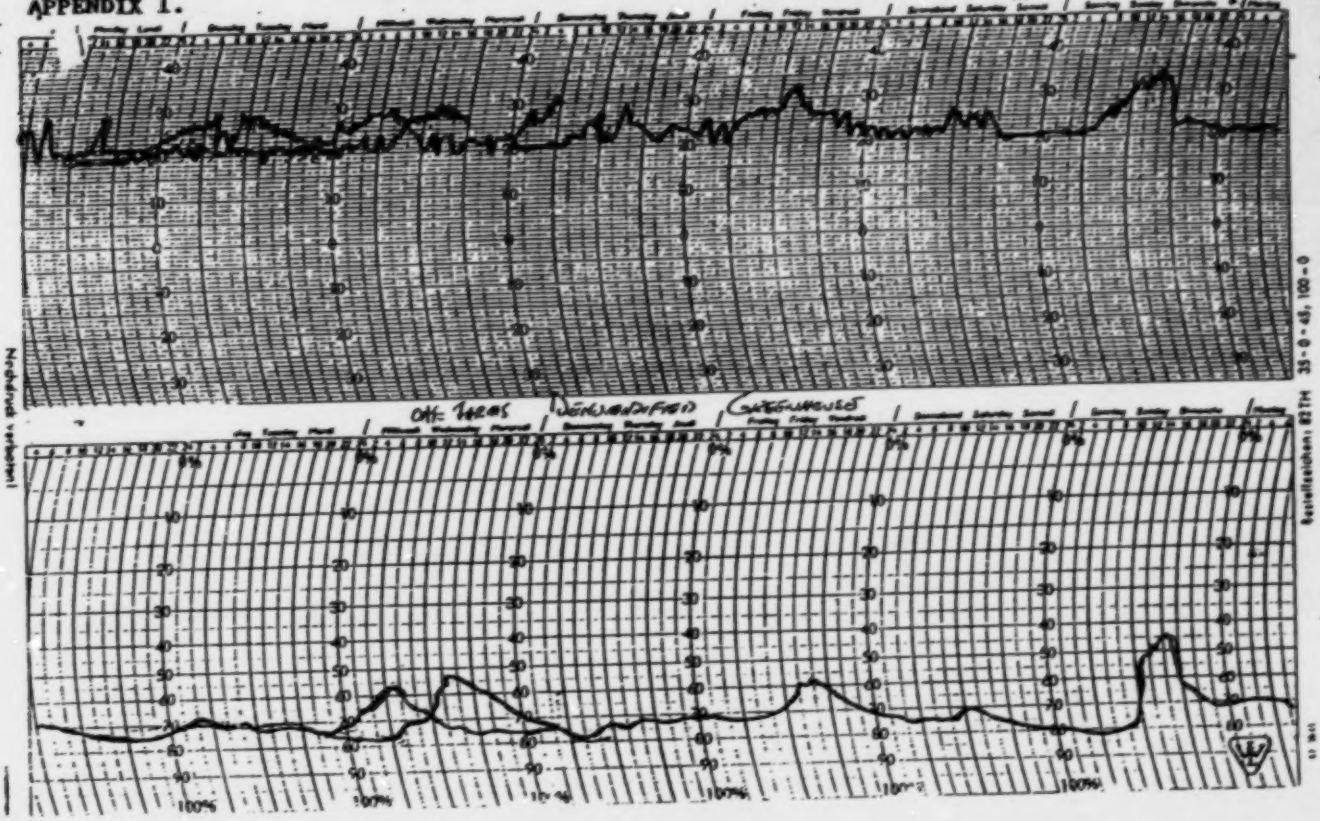
TABLE #2

CONDENSATE & ELECTRICAL CONSUMPTION

OAK FARMS DEHUMIDIFIER

DATE 1985	TIME	DEHUMIDIFIER CONDENSATE m^3	METER	kWh METER READING	(X 100) MULTIPLIER
Feb. 27	17:15	2.08		28	
Mar. 07	13:35	2.64		30	
Mar. 13	13:20	3.07		41	
Mar. 21	13:25	3.35		47	
Apr. 11	13:45	3.38		57	
Mar. 17 1986	13:30	7.78		185	
Mar. 24	12:00	8.01		192	
Apr. 02	13:00	8.45		201	
Apr. 17	15:00	8.78		216	
Dec. 09	16:30	10.85		236	
Dec. 30 1987	10:45	10.93		244	
Jan. 07	11:30	11.17		251	
Jan. 13	15:00	11.40		257	
Jan. 21	11:00	11.55		263	
Jan. 27	12:00	11.63		268	
Feb. 16	11:30	11.63		269	

APPENDIX 1.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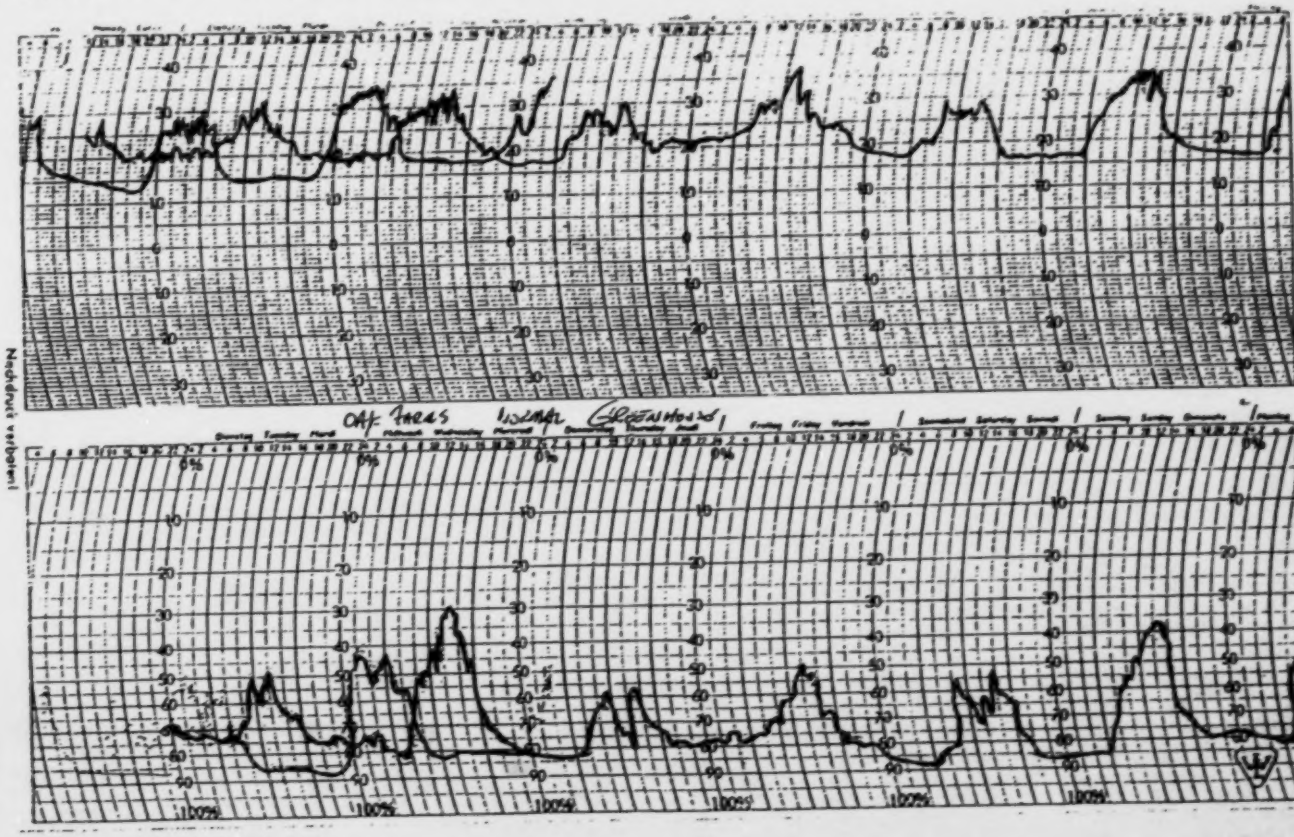
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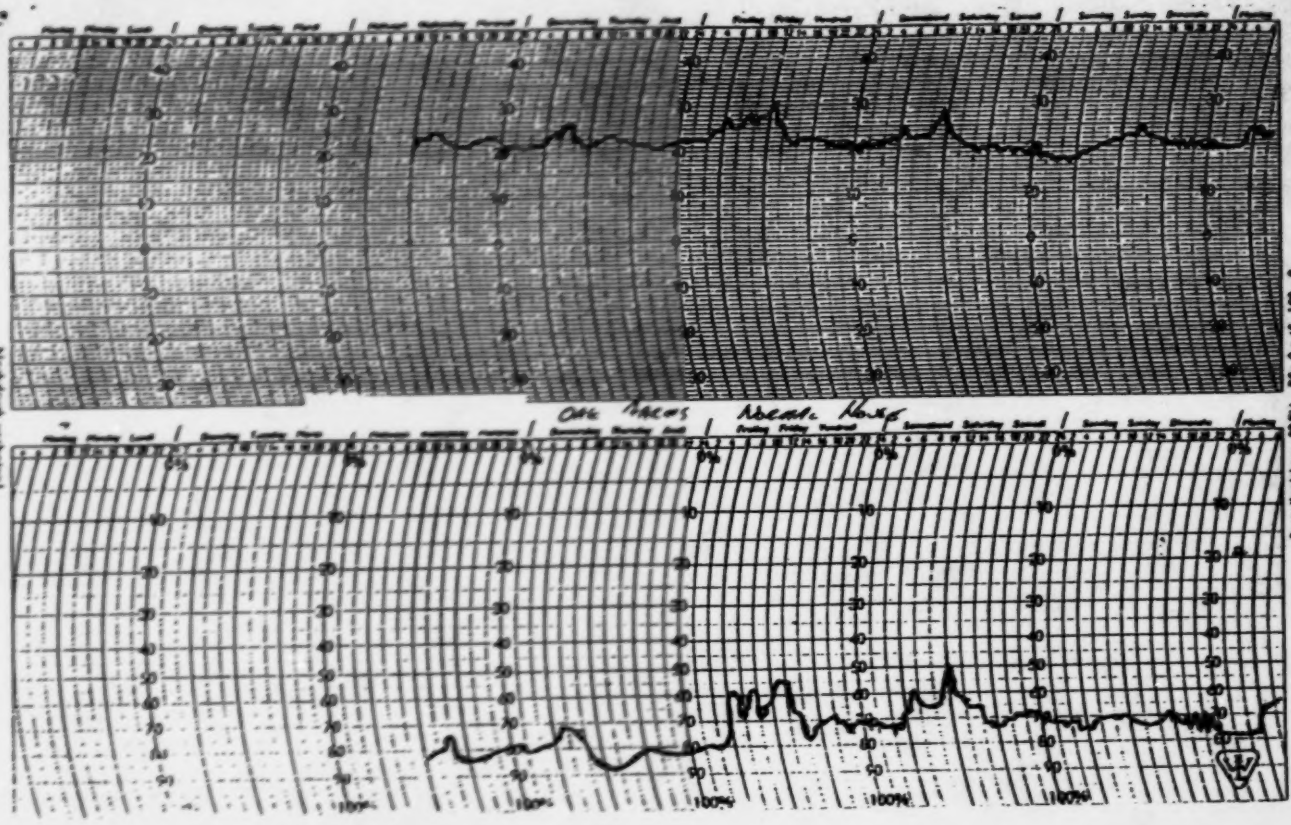
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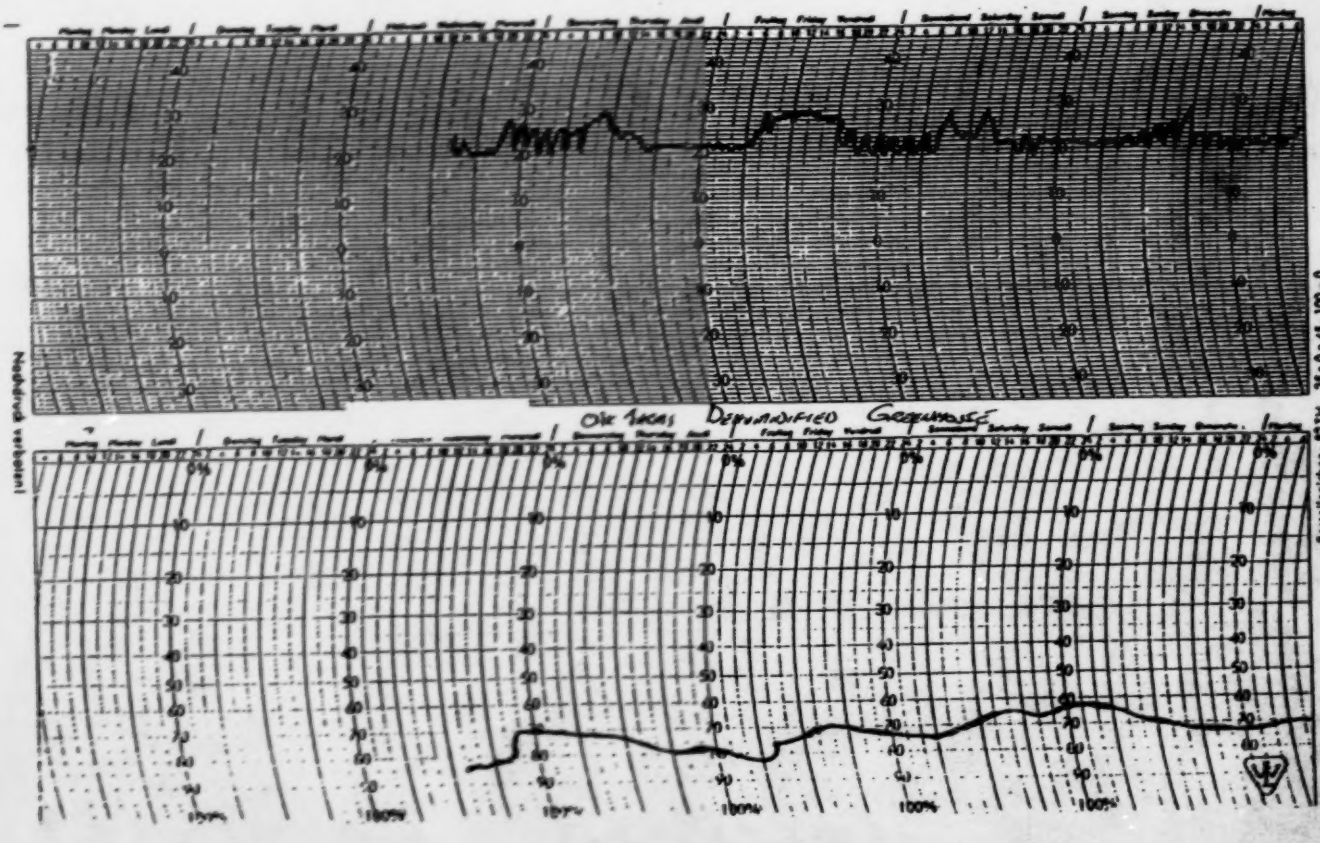
33-0-45, 100-0
Bestellzeichen: 62TH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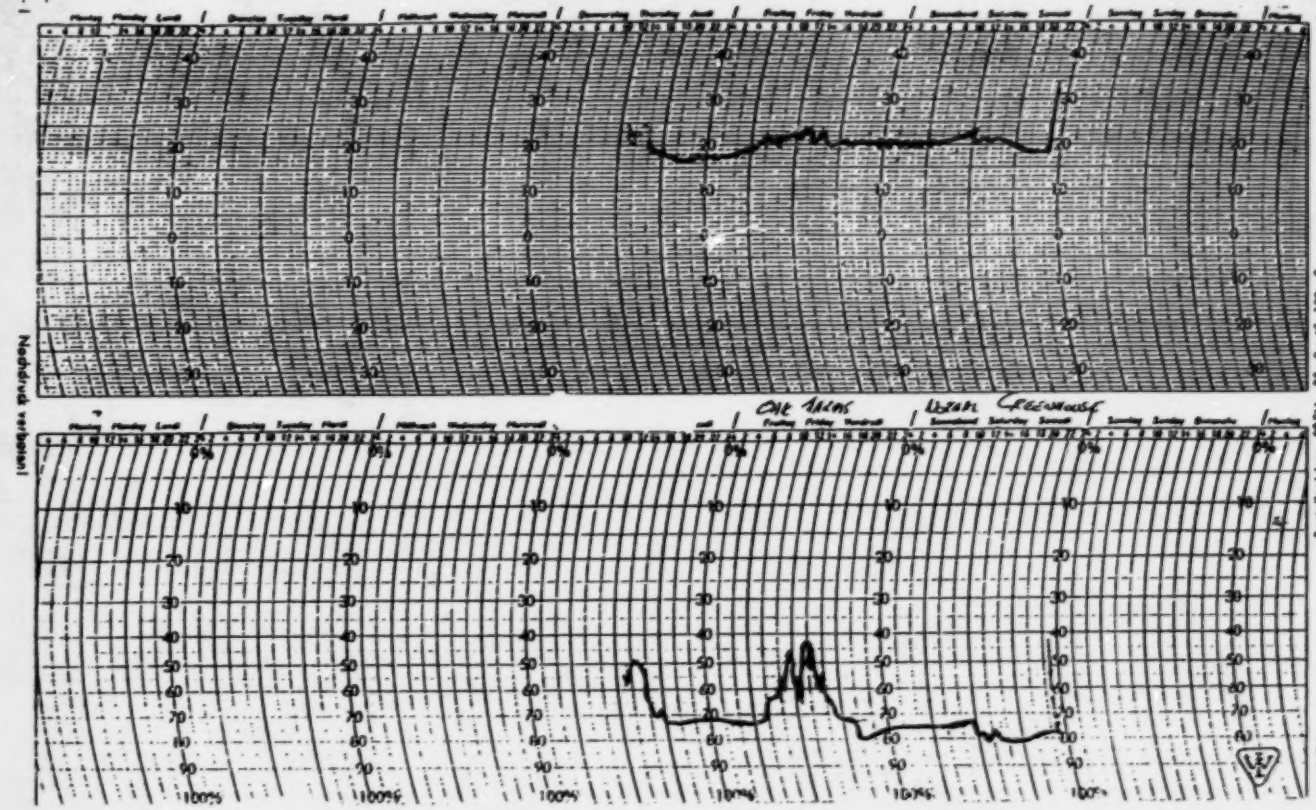
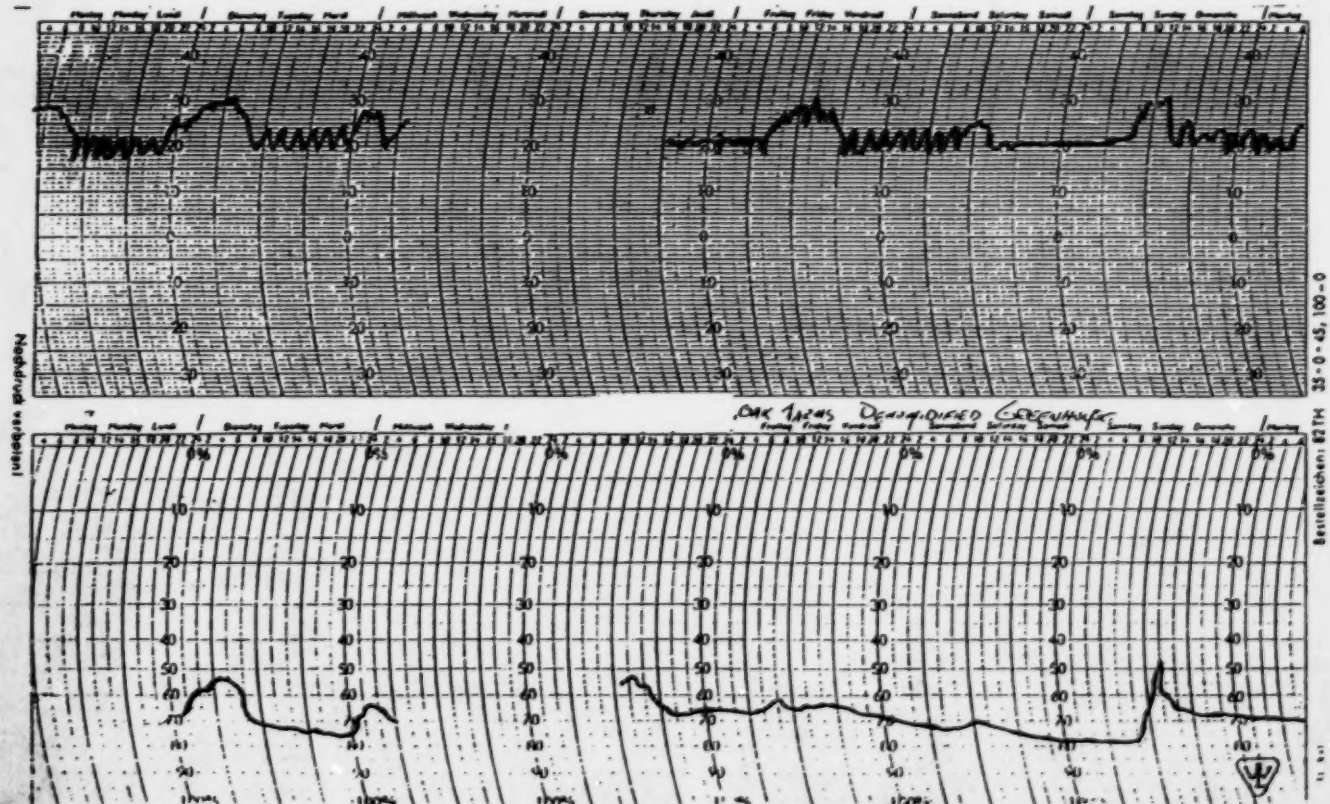
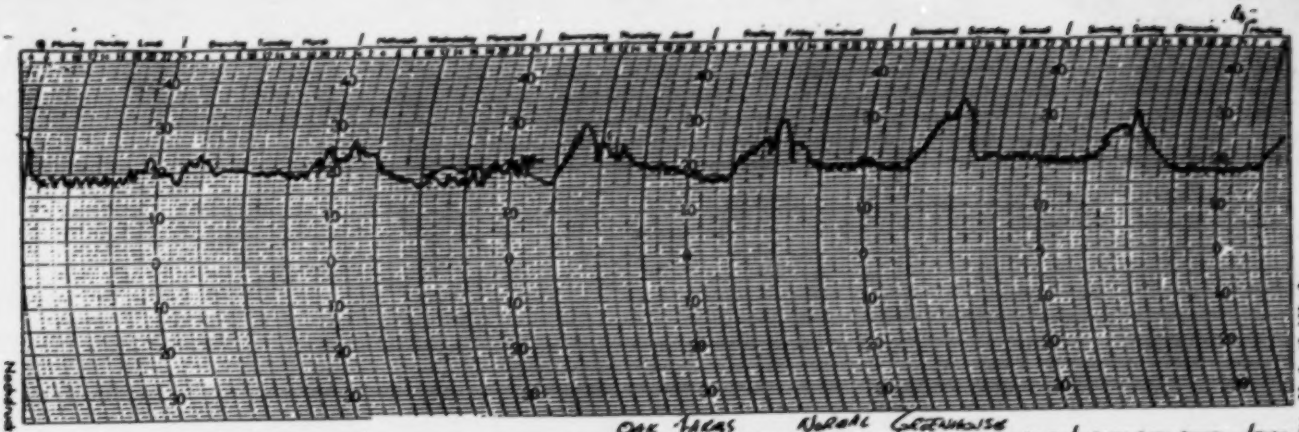
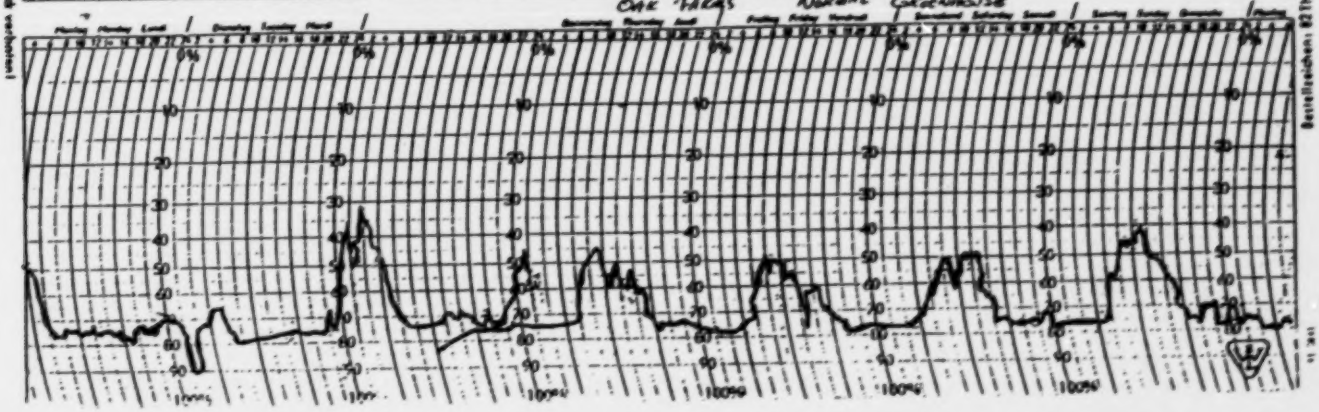
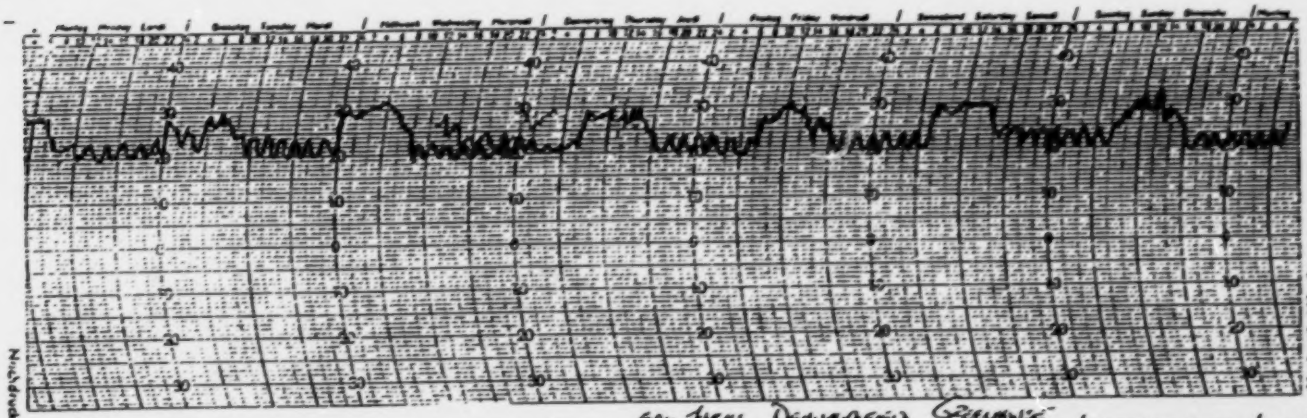
33-0-45, 100-0
Bestellzeichen: 62TH

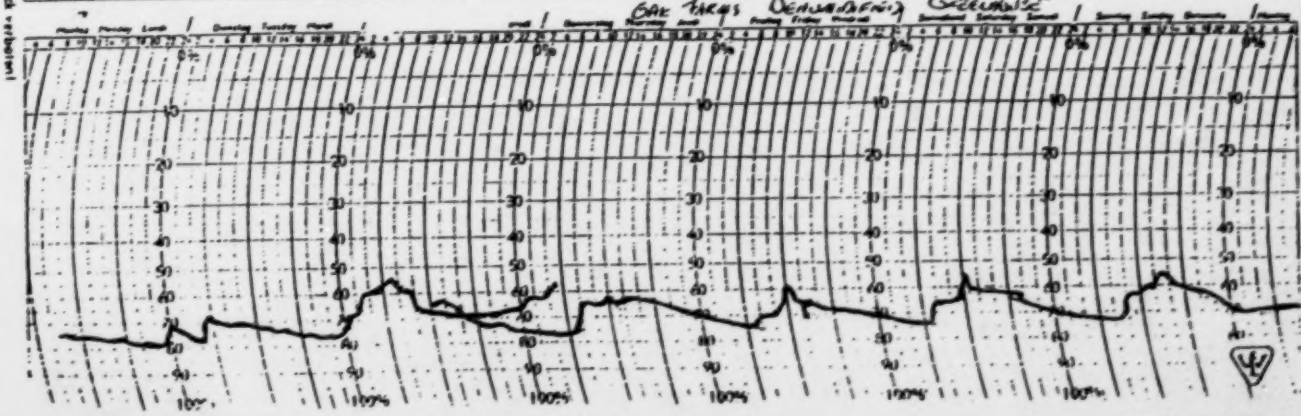

OAK TREES
WOOD GREENHOUSE
33-0-45, 100-0
Bestellzeichen: EZTH

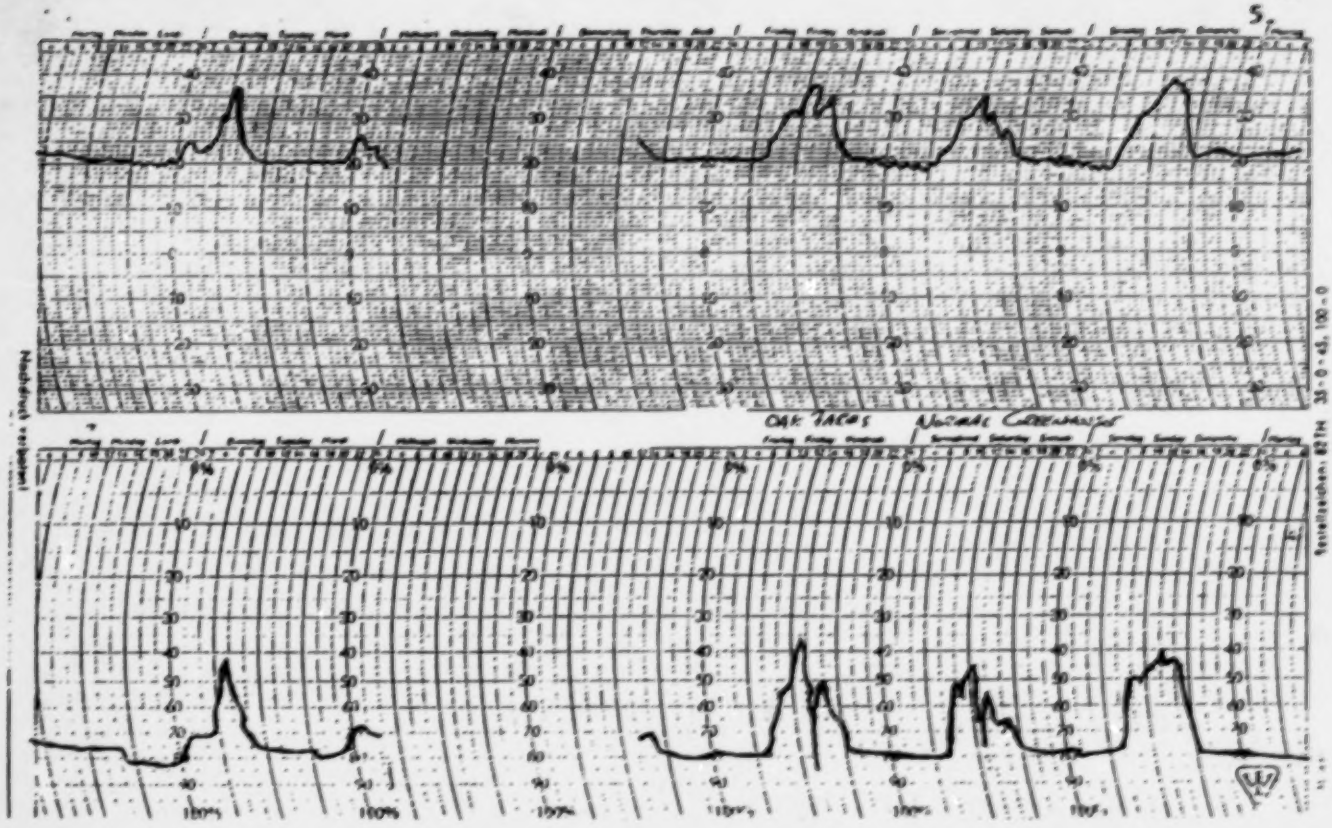

OAK TREES
DEAD WOOD GREENHOUSE
33-0-45, 100-0
Bestellzeichen: EZTH

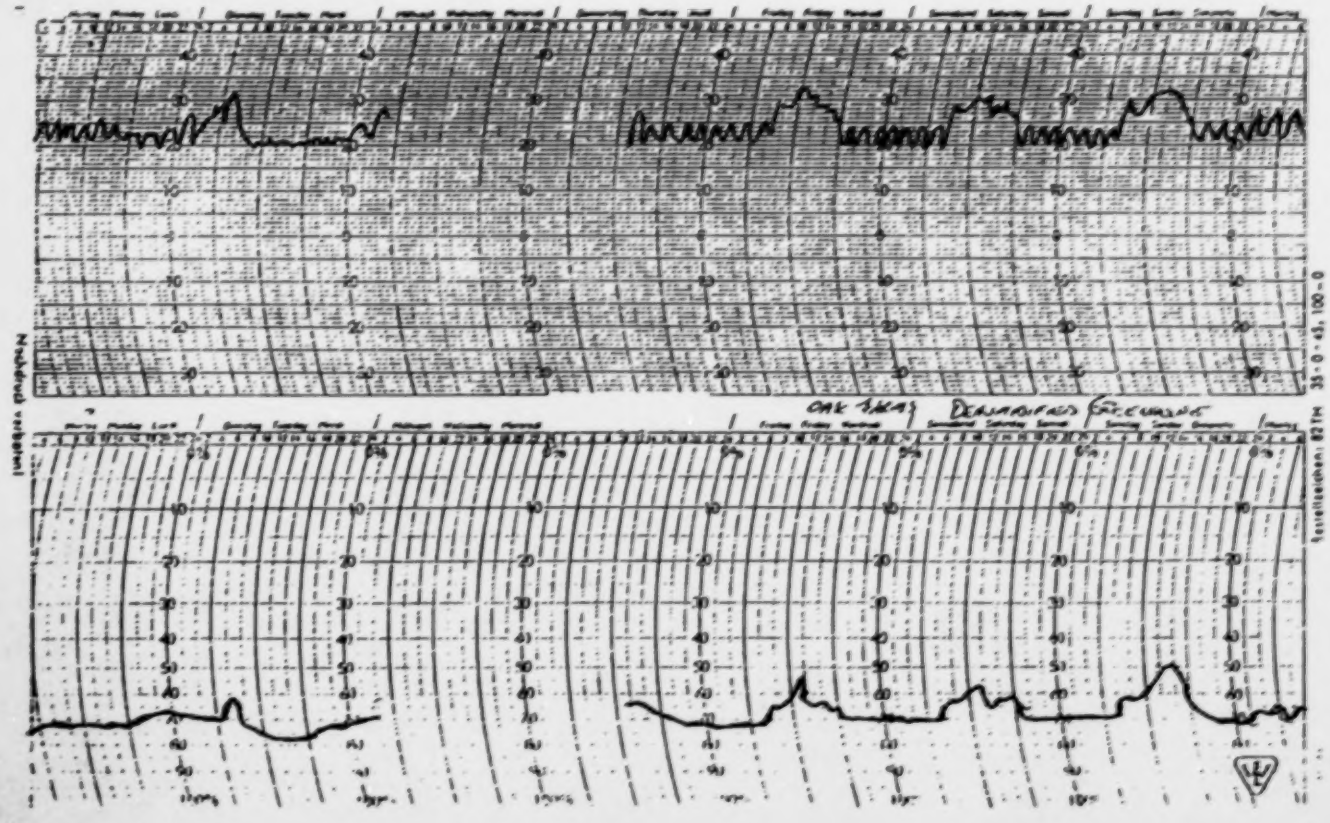



OAK TARAS NORMAL GREENHOUSE




OAK TARAS DEHUMIDIFIED GREENHOUSE


OAK TREES
NORMAL CONDITIONS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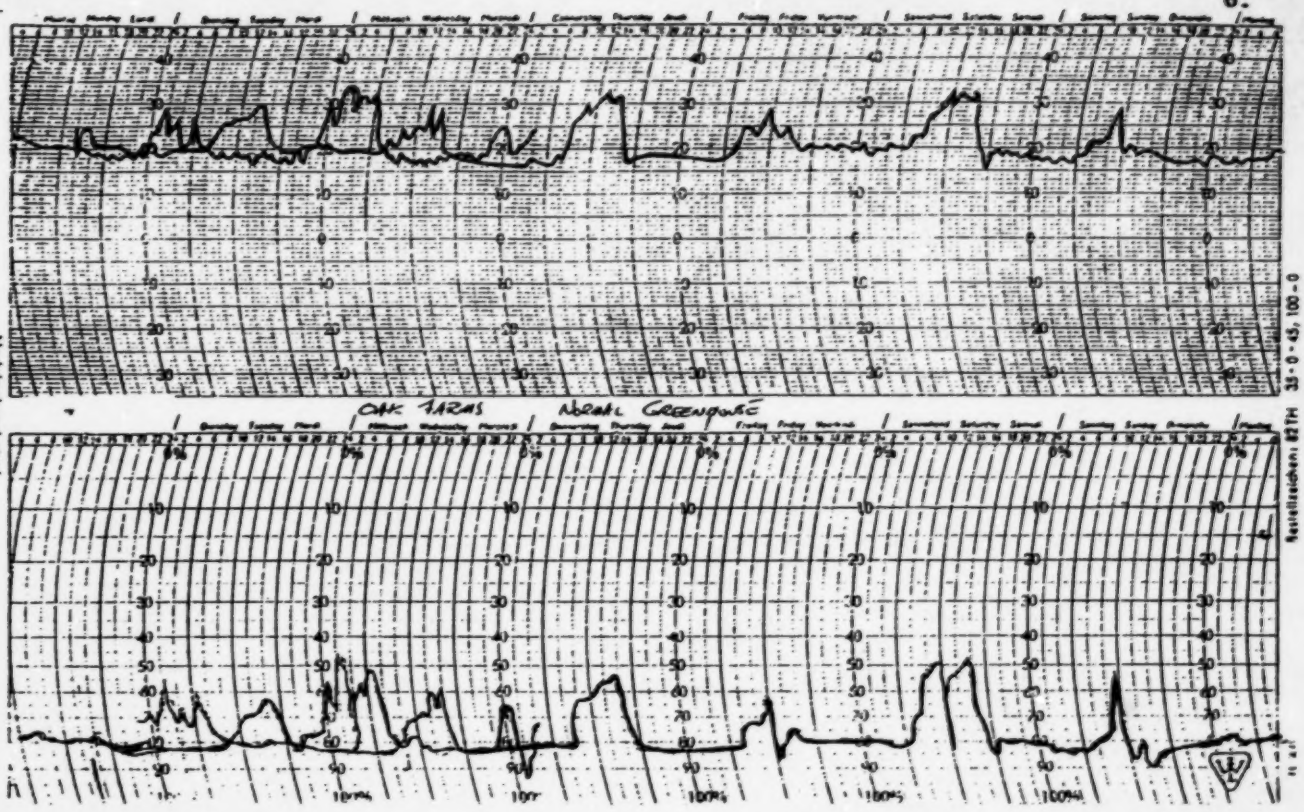
DEFOLIATED CONDITIONS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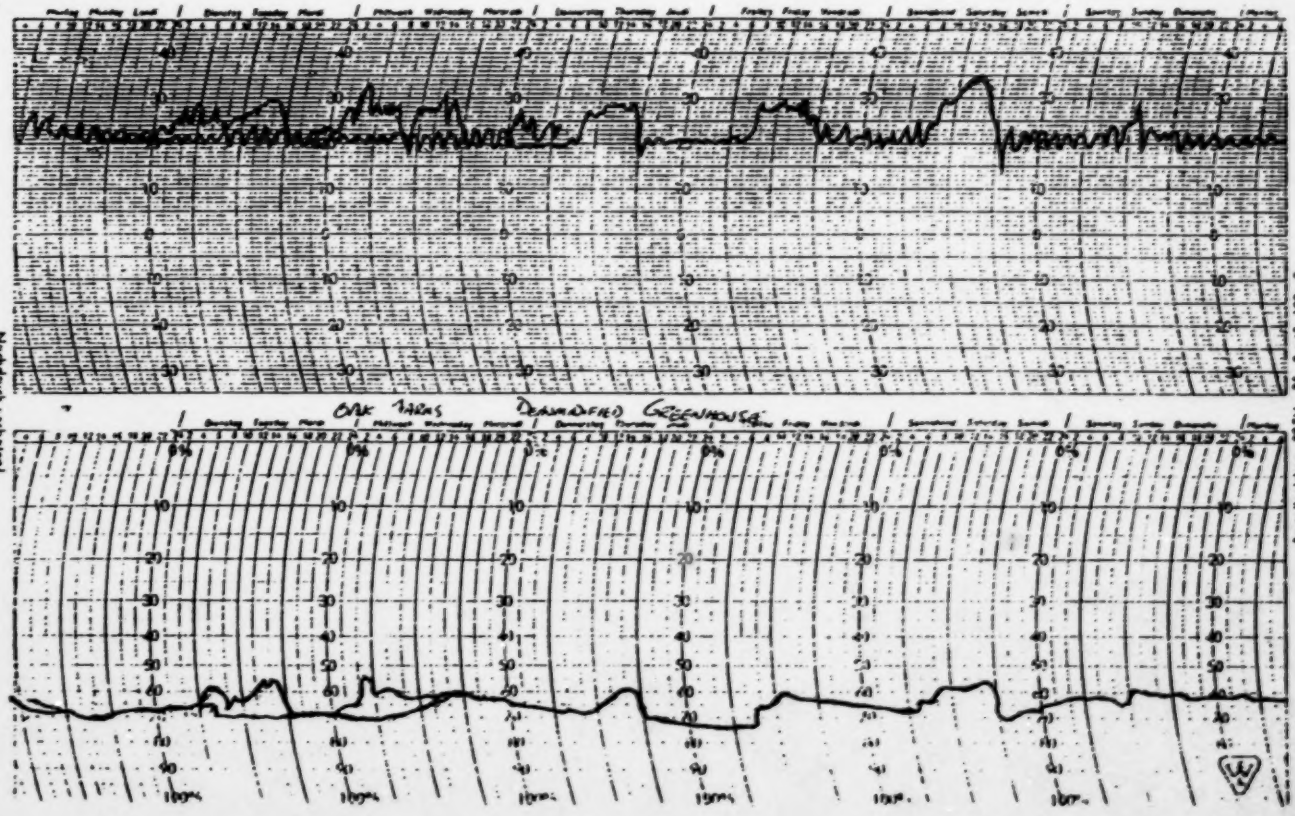
OAK TARAS
DEHUMIDIFIED GREENHOUSE